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ORIGINAL ARTICLE

Evaluation of tracheal intubation: A retrospective study of skill acquisition by medical students in the operating theater

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Background/Purpose: Tracheal intubation is a critical life-saving invasive procedure. Medical students generally obtain the skill of performing tracheal intubation in the operating theater during their anesthesiology rotation. In this study, we sought to characterize medical students' skill acquisition of tracheal intubation.

Methods: We retrospectively reviewed the logbooks of 94 medical students who had completed a 3–4 week rotation in our department between January 2011 and June 2012.

Results: Ninety-four students performed 934 tracheal intubations. The success rate of intubation was 76.7%. After adjustment for age, body mass index, Mallampati class and grade, American Society of Anesthesiology (ASA) scores, and surgical category, the odds ratio of successful tracheal intubation improved with cumulative practice [odds ratio (OR) = 1.05 for each additional intubation performed; 95% confidence interval (CI) 1.00–1.09]. By contrast, the success rate decreased significantly with increasing scores of Mallampati class (OR = 0.32 for each increase in class; 95% CI 0.23–0.24) and grade (OR = 0.57 for each increase in grade; 95% CI 0.39–0.84). The main reason for intubation failure (57%) was poor visualization of vocal cords, due to suboptimal placement of the position of the laryngoscope. The satisfaction and confidence of students regarding the ability of performing tracheal intubation increased with each additional procedure, but decreased significantly after multiple unsuccessful attempts and the occurrence of any complication.

Conclusion: Medical students acquired the ability of tracheal intubation and overcame major challenges through cumulative clinical practice of the procedure.

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Introduction

Life-saving procedures are generally taught to medical students during their hospital training. Tracheal intubation remains a critical procedure in emergency airway management. Numerous studies have consistently shown improved outcomes in critically ill trauma patients when the airways were secured by an endotracheal tube as early as possible.[1,2] Unfortunately, many residents reported a lack of confidence in performing the invasive bedside procedures, including tracheal intubation to their patients.[3] Teaching tracheal intubation to medical students should be a paramount goal in academic anesthesia departments, because it is clearly beneficial for students to be able to perform intubation confidently in their future careers.[4,5] Therefore, we put many efforts to achieve this goal in our department.

In general, students acquire the skill of performing tracheal intubation through repetitive task practice. Unfortunately, the opportunity of learning tracheal intubation on patients in the operating theater is currently limited. Indeed, an increasing number of intubations has not paralleled the constantly rising number of trainees. This may be due, at least in part, to the rising use of laryngeal mask airway placement in patients undergoing general anesthesia.

In the present study, we sought to evaluate the clinical performance of medical students' tracheal intubations under our current teaching program.

Methods

Ethical approval for this retrospective study (20121108RIC) was provided by the Institutional Review Board of the National Taiwan University Hospital, Taipei, Taiwan on 20 December 2012. In order to review the clinical performance and the tracheal intubation skill acquisition, we examined the logbooks of 94 medical students, who underwent a 3–4 week rotation in our anesthesiology department between January 2011 and June 2012. All of the students participating in the study received an adequate training in basic airway management, including mask ventilation, nasal and oral airway placement, laryngeal mask airway insertion, and tracheal intubation. Under the supervision of a senior anesthesiologist, all of the students initially performed tracheal intubation on manikin simulators. Every student had a step-by-step checklist to perform tracheal intubation. After a 2-day training session, the students observed each step of tracheal intubation as demonstrated by experienced anesthesiologists in the operating theater. Prior to performing tracheal intubation on a patient, medical students should study the American Society of Anesthesiology (ASA) physical status classification, brief history, type of surgery to perform, age, sex, weight, height, and Mallampati score of the patient. Medical students were allowed to perform tracheal intubation only on patients with ASA I–III who were undergoing general anesthesia with muscle relaxation. A supervisor was present during every tracheal intubation performed by a medical student from the beginning to the completion of the procedure. After placing the monitors, a student pre-oxygenated the patient with pure oxygen during the administration of induction agents (2–4 μg/kg fentanyl; 0.5–1.0 mg/kg lidocaine; 1.5–2.5 mg/kg propofol; 0.1–0.15 mg/kg rocuronium). While placing the laryngoscope into the mouth to expose the vocal cords, students reported the patient's Mallampati score to their supervisor and then placed the tube through the vocal cords, or asked for optimized maneuvers to facilitate tracheal intubation. After each intubation, the students were required to complete their structured logbook, including information on the number of attempts, Mallampati class and score,[6,7] and the final tracheal intubation outcome (success or failure). If the attempt failed or any complication occurred, the reasons for unsuccessful intubation were discussed between the students and their supervisors. Students were also asked to provide a satisfaction score regarding the last tracheal intubation performed on a four-point scale (from 1 = disappointed to 4 = highly satisfied). Similarly, they were requested to grade on a four-point scale their confidence for a subsequent tracheal intubation (from 1 = not confident to 4 = highly confident).

A tracheal intubation attempt was defined as a direct laryngoscopy for visualizing the vocal cords and placing an endotracheal tube into the trachea. Tracheal intubation failures were defined as an inability to place the endotracheal tube, or the intubation was taken over by the supervising anesthesiologist, usually after three attempts, or any situation that was considered harmful to the patients (hypertension, desaturation, or tachycardia).

Statistical analysis

The baseline characteristics are presented using descriptive statistics. Categorical data are expressed as counts, whereas continuous variables are given as mean ± standard deviations. Univariate analysis was performed using a simple generalized linear model for both categorical and continuous variables. Results were expressed as odds ratios (ORs) with 95% confidence intervals (CIs). All of the significant variables identified in univariate analysis were entered into a multiple generalized linear regression model. The generalized estimating equations method was used to correlate the response data. All calculations were performed using the R software for Windows, version 2.12.0 (The R Foundation for Statistical Computing, Vienna, Austria; 2010). Two-tailed p values <0.05 were considered statistically significant.

Results

Ninety-four students performed 927 tracheal intubations on patients receiving general anesthesia during the 18-month study period. The mean number of intubations per student was 9.9 ± 2.7. Twenty-three (24.5%) students performed one to five intubations, 60 (63.8%) performed 6–10 intubations, seven (7.4%) performed 11–15 intubations, and four (4.2%) performed more than 15 intubations. The general characteristics of the study patients and the students' performances are presented in Table 1.

The overall successful rate of tracheal intubations performed by medical students was 76.8% (712/927 patients). Of these, 589 intubations were successfully performed

Table 1 Patients' characteristics and students' tracheal intubation performances.

Variables	Failure		Success	
	$n = 218$	%	$n = 716$	%
Sex				
Female	99	0.46	363	0.51
Male	116	0.54	349	0.49
ASA				
I	22	0.10	84	0.12
II	113	0.53	412	0.59
III	78	0.37	203	0.29
Specialty				
General surgery	123	0.56	412	0.58
Neurosurgery	40	0.18	93	0.13
Ear-nose-throat surgery	18	0.08	78	0.11
Urology surgery	10	0.04	41	0.06
Chest surgery	11	0.05	29	0.04
Plastic surgery	6	0.03	19	0.03
Orthopedic surgery	8	0.04	15	0.02
Gynecology surgery	1	0.01	18	0.03
Cardiovascular surgery	1	0.01	11	0.02
Mallampati class				
Class 1	18	0.09	143	0.21
Class 2	128	0.61	461	0.68
Class 3	62	0.30	76	0.11
Class 4	1	0.01	1	0.01
Mallampati grade				
Grade 1	31	0.15	246	0.36
Grade 2	99	0.47	383	0.56
Grade 3	66	0.32	54	0.08
Grade 4	13	0.06	1	0.01
Attempt				
1 try	3	0.38	589	0.86
2 tries	5	0.63	90	0.13
3 tries	0	0.00	4	0.01
Mucosal injury	20		25	
Satisfaction				
Disappointed	46	0.23	18	0.03
Not satisfied	132	0.65	245	0.36
Satisfied	23	0.11	294	0.43
Greatly satisfied	3	0.01	122	0.18
Confidence				
Not confident	48	0.24	53	0.08
Moderately confident	112	0.55	292	0.43
Confident	43	0.21	327	0.48
Highly confident	0	0.00	7	0.01
Failure reason				
Poor blade position	125	0.57		
Difficult airway	57	0.26		
Trismus	17	0.08		
Miscellaneous	19	0.09		

after a single attempt, 90 after two attempts, and four after three attempts. Minor complications (mainly mucosal laceration and bleeding) occurred in 45 patients.

The most common reason for tracheal intubation failure was the inadequacy of the student's skills, such as the laryngoscope not being placed in the optimal position so that the visualization of the vocal cords was difficult, or the patient's tongue was obstructing the path of the endotracheal tube. The second and third most common reasons were the presence of a relatively difficult airway and limited mouth opening, respectively. The remaining failures were due to the patient's vital signs, bulking, or choosing a wrong size of the endotracheal tube.

Simple univariate analysis showed that the number of tracheal intubations the student had performed, age, ASA physical status, and both Mallampati class and grade were significantly associated with the intubation success rate. After allowance for potential confounders in multiple regression analysis, the number of successful tracheal intubations was found to be independently associated with the cumulative number of tracheal intubations that had been performed, and both Mallampati class and grade. For each additional intubation performed by the student, the subsequent intubation was 1.05-fold more likely to be successful (Table 2). By contrast, the odds of a successful intubation were found to be significantly reduced for each increase in both Mallampati class and grade (OR = 0.32 and OR = 0.57, respectively).

The satisfaction in tracheal intubation performance by the medical students was found to increase in parallel with repetitive task practicing. By contrast, the satisfaction score decreased significantly when there was a failure to intubate a patient's trachea, there was more than one intubation attempt, and occurrence of a complication was present (Table 3). Similarly, the students' confidence for future intubation was found to increase with the number of intubations performed, and to decrease with the number of attempts, and the occurrence of failures and complications (Table 4).

Discussion

The overall success rate of tracheal intubations performed by medical students in our report was 76.8%, which is in accordance with the results obtained by Tarasi et al.[8] If the tracheal intubation skill acquisition had to be increased in order to achieve a success rate >90%, then the students would have to practice more than 27 tracheal intubations according to the learning curve observed in our study (Fig. 1). Unfortunately, medical students are facing limited opportunities for performing tracheal intubations, because many patients undergoing general anesthesia receive a laryngeal airway mask instead of an endotracheal tube, and procedures performed under combined intravenous anesthesia with regional nerve blockade are also common in our hospital. The number of trainees is rising, whereas the number of patients requiring tracheal intubation has not been increasing in parallel. Junior residents, anesthesia student nurses, and paramedic students are currently competing with medical students on rotation in the anesthesia department for learning tracheal intubation skills. The identification of the main reasons of tracheal intubation failures may ultimately improve the students' performances. In this study, 57% of tracheal intubation failures were due to suboptimal exposure of the vocal cords with the laryngoscope, ultimately leading to a poor visualization of the vocal cords. Repetitive task practice would be the ideal solution for improving the intubation success rate. However, gaining clinical experience in the operating

Table 2 Association between the likelihood of successful tracheal intubation and the patients' general characteristics.

Variables	Univariate analysis		Multivariate analysis	
	Odds ratio	*p*	Odds ratio	*p*
Number of intubations	1.04 (1.00–1.07)	0.042*	1.05 (1.00–1.09)	0.028*
Age	0.99 (0.98–0.99)	0.002*	0.99 (0.98–1.00)	0.124
Sex				
Female	0.80 (0.60–1.06)	0.117		
Male	1.00			
Height	0.99 (0.97–1.00)	0.126		
Weight	0.99 (0.98–1.01)	0.223		
Body mass index	0.99 (0.94–1.04)	0.646		
ASA score	0.78 (0.61–0.99)	0.040*	1.14 (0.87–1.49)	0.349
Specialty				
Cardiovascular surgery	4.30 (0.30–62.71)	0.286		
Gynecology surgery	5.72 (0.59–55.32)	0.132		
Orthopedic surgery	0.59 (0.24–1.42)	0.238		
Plastic surgery	1.01 (0.41–2.49)	0.990		
Chest surgery	0.81 (0.35–1.88)	0.620		
Urology surgery	1.26 (0.59–2.66)	0.551		
Ear-nose-throat surgery	1.32 (0.77–2.25)	0.315		
Neurosurgery	0.70 (0.48–1.03)	0.072		
General surgery	1.00			
Mallampati class	0.37 (0.26–0.52)	<0.001*	0.57 (0.39–0.84)	0.004*
Mallampati grade	0.27 (0.20–0.37)	<0.001*	0.32 (0.23–0.43)	<0.001*

* Denotes statistically significant associations.

theater remains problematic for students. In this scenario, a potentially valuable alternative would be to rely on improved teaching protocols on manikin simulators. Previous studies have demonstrated the usefulness of teaching students tracheal intubation using manikins to perfect their technical skills.[9–11] Manikins are good for hands-on practice of trachea intubations for medical students. They can learn how to hold the laryngoscope, open the manikin's mouth, and insert the laryngoscope to move the tongue to the left side of the mouth cavity. After they are familiar with the steps, students learn how to exert force properly, axially on the laryngoscope to lift the jaw and submandibular tissues, and make a clear path for the tracheal tube. At the same time, students should avoid any collisions of the blade with the teeth or soft tissues. Students can adjust their manipulations of the laryngoscope blade and intubation tube on manikins as many times as they need, until they gain the skills. Prior to practicing intubation in a clinical setting, a test on a manikin is essential to ensure that the students have acquired the necessary proficiency in each step of tracheal intubation.

The majority of our medical students were able to perform a successful intubation after a single attempt, and 14% of the successful tracheal intubations were accomplished at the second attempt. Therefore, when the students fail at the first attempt and the patient is in the presence of stable clinical conditions, we may give them the opportunity of a second attempt. Another 52 tracheal intubations failed because of high Mallampati grades of vocal cords. Sometimes, it is helpful to flex the patient's head to obtain a better view of the vocal cords with high Mallampati grades. A valuable alternative is the application of the optimization maneuver (backward, upward, and rightward pressure; BURP) on the thyroid cartilage. Such an

Table 3 Students' satisfaction with their tracheal intubation performance.

Variables	Coefficient	*p*
Number of intubations performed	0.04 (0.02–0.06)	<0.001
Failures		
No	0	
Yes	−0.83 (−0.97 to−0.69)	<0.001
Complications		
No	0	
Yes	−0.50 (−0.71 to −0.28)	<0.001
Attempts	−0.33 (−0.46 to −0.19)	<0.001

Table 4 Student confidence for their next tracheal intubation.

Variables	Coefficient	*p*
Number of intubations performed	0.03 (0.02–0.04)	<0.001
Failures		
No	0	
Yes	−0.44 (−0.56 to −0.32)	<0.001
Complications		
No	0	
Yes	−0.29 (−0.49 to −0.10)	<0.001
Attempts	−0.25 (−0.39 to −0.15)	0.004

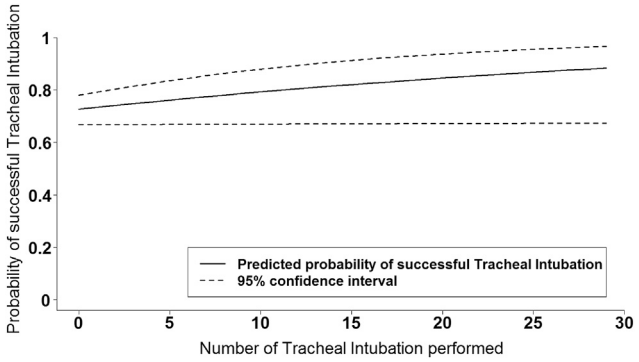

Figure 1 Learning curve of successful tracheal intubation in medical students.

approach frequently improves the laryngeal view and facilitates a successful tracheal intubation. In this study, 16 cases (7%) failed because of a difficulty in opening the patient's mouth adequately. Several reasons may be responsible for this phenomenon, including the presence of trismus, the absence of full paralysis at the time of laryngoscopy attempt, and the presence of suboptimal intubation skills. A potential solution is to ensure that the patient has achieved a complete muscle blockade prior to starting the intubation.

Some caveats of our study merit comment. First, our research is limited by its retrospective design and its reliance on medical students' logbooks. Second, some students participating in this study were offered a chance to perform several attempts, whereas this possibility was denied to others. The presence of different supervisor-student interactions may be a potential explanation for such variability. Some supervisors may be especially cautious about patient safety. Students might get only one attempt to perform a tracheal intubation on the patient. The satisfaction and confidence of medical students were negatively affected by their failure. Notably, a marked negative attitude was evident from the medical students' logbooks after a failed attempt, which resulted in a higher number of missing data, and the total number of attempts was frequently unavailable. Third, some potential confounders (including the patients' vital signs and the intubation time) were not included in the logbooks. Finally, the reasons whereby some students performed less than 10 tracheal intubations are unclear.

We believe that the performance of tracheal intubation by students can be improved further, and the satisfaction and confidence will be boosted if we revise our teaching methods. Potential strategies to achieve this goal include a better use of manikins to practice tracheal intubation and a careful skill evaluation on manikins prior to attempting intubation in the operating theater. Importantly, learning how to deal with failed tracheal intubation attempts is critical for developing motivation and successful learning. Medical students should learn that they can and must learn from their mistakes. In summary, the results of this study indicate that the acquisition of the tracheal intubation skills increased significantly through the cumulative clinical experience.

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